MODIS Semi-Annual Report
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SUMMARY

1. Accomplishments

- ATBDs: The 4 ATBDs were updated and delivered on time (in collaboration with C. Justice and D. Tanré, and participation by B.-C. Gao, L. Remer and E. Vermote). The main advances were in the ATBD for remote sensing of aerosol, and in the ATBD for remote sensing of fires. Some new technical aspects of the ATBD for remote sensing of water vapor in the NIR and ATBD for atmospheric corrections were included.

- AEROSOL MODELS: A major thrust of present research is in developing better physical and optical models of aerosol for remote sensing. Ground based measurements during SCAR-A are being analyzed for the aerosol size distribution and related to meteorological parameters. A clear model is emerging. A theoretical model for the dynamical evolution of aerosol size distribution in the presence of atmospheric processes was developed and used to show that the sulfate aerosol effect on cloud microphysics is 4 times larger than postulated in previous works. A paper on the issue was published in Nature (Kaufman and Tanré, 1994). Measurements in other locations are being acquired (Holben, Tanré and Kaufman in collaboration with many others).

- AEROSOL OVER OCEANS - the algorithm, by Tanré and Kaufman for remote sensing of aerosol loading and size distribution over the oceans was developed. The emphasize is on use of wide spectral range, till 2.1 µm or 3.9 µm in order to be able to distinguish between the small and large aerosol particles. Simulations and sensitivity studies are being performed.

- AEROSOL OVER LAND - First version of the program for remote sensing of aerosol over the land was finished and delivered. A sensitivity study and simulation was performed. Preparation for application to SCAR-A data are under way.

- SCAR-A DATA SET - SCAR data set (MAS, AVIRIS, TM, AVHRR) is being acquired, calibration issues resolved, and data prepared for application of MODIS algorithms.

- FIRES - The algorithm for remote sensing of fires was modified to include two main parameters: the total thermal energy emitted from the fire and ratio between the fraction of this energy being emitted from smoldering stage and flaming stage. This is expected to make the algorithm much more useful for the users community (e.g. discussions with the Forest Service Fire Lab scientists). Sensitivity study was done. Preparation for application of the algorithm to Yellowstone fires are under way.

2. Future plans:

- SCAR-C experiment - Sept./Oct. 1994 California, Oregon and Washington to measure fires and smoke. Next preparation meeting in Aug. 15.
- SCAR-B experiment - 1995: Coordination meeting in Brazil in Aug. 5-8
- First version for software for atmospheric corrections to be delivered in Oct.
- First version for software for remote sensing of water vapor to be delivered in Oct.
- First version for software for remote sensing of fires Oct.-Feb., 1995.
- Sensitivity studies and application of MODIS software to SCAR-A data May-Dec.

Detailed report

1. SCAR -A

We continue to analyze the data collected during the SCAR-A experiment.

1.1 Surface reflectance properties in the visible and at 2.1 μm

We are using the SCAR-A data and other data sets to etablish the relationship between the surface reflectance in the blue and red channels and the reflectance at 2.1 μm. At 2.1 μm the aerosol effect is 3-5 times smaller than in the red and blue channels. We shall use this fact and the expectation that the surface properties in the red and blue are highly correlated with the reflectance at 2.1 μm, to develop the method for remote sensing of aerosol over the land.

A TM image of the Great Dismal Swamp area for July 28 was corrected for Rayleigh and aerosol scattering and water vapor absorption using data from the Hampton Roads sunphotometer. Twenty-three targets were chosen from this image including a lake, dark forest, agricultural fields, bare soil, and residential parts of Norfolk. Corrected surface reflectances show that the 2.1 μm surface reflectances are linearly correlated with the visible surface reflectances and that the reflectance at 0.47 μm can be approximated as 25% of the reflectance at 2.1 μm while the reflectance at 0.66 μm is approximately 50% of that at 2.1 μm.

Several AVIRIS scenes of the same area as the TM image described above but for July 16 were also corrected for Rayleigh, aerosol scattering and water vapor absorption. The appropriate 10 nm AVIRIS bands were averaged to resemble the wider TM channels. Targets were selected from these scenes including several of the same targets chosen for the TM image. The results from the July 16 AVIRIS scenes agree with the conclusions of the July 28 TM image with the same relationship between the blue, red and 2.1 μm channels.

We have identified targets in TM and AVIRIS images in other geographic regions with different terrain and vegetation cover. After the atmospheric correction is completed for these images, our data base of surface properties will be expanded.

1.2 Modeling of atmospheric aerosol using SCAR-A data

We continue to use the size distributions calculated from sunphotometer data, averaged and sorted according to aerosol optical thickness to develop an atmospheric aerosol model representative of the eastern U.S. We compare four days of these data at specific sunphotometer sites with in situ data measured at various altitudes by the C-131A aircraft above the specific sunphotometer. The size distributions from sunphotometer remote sensing show remarkable similarity to those measured in situ by the aircraft. There are still uncertainties in the sunphotometer data for radii less than 0.1 µm and also for very large radii. We hope to reduce these uncertainties for small radii by testing the robustness of our lognormal fits and also by further comparisons with the aircraft data (other variables such as CCN etc.).

We have modeled the aerosol size distribution data as a sum of five lognormals: a coarse mode (effective particle radius, r_m, greater than 4 µm), a salt mode (r_m equal to 1.3 µm), a mode representing stratospheric aerosols (r_m equal to 0.55 µm) and two modes representing sulfates and other particles created from gases (r_m equal to 0.032 µm and 0.21 µm). The two mode sulfate model represents the two different processes which create these particles. The smaller particles (0.03 effective mean radius) result from gas-to particle conversions in air. The larger sulfate particles (0.21 effective mean radius) result through cloud processes. Our model shows that at low optical thickness the 0.21 µm mode is non-existent, that as optical thickness increases both the 0.032 µm and 0.21 µm modes increase in volume density but that the rate of incerease of the 0.21 µm mode is faster, and that for large optical thicknesses the 0.21 µm mode dominates the sulfate signal. Previous work using a single lognormal to represent the sulfate particles suggested a change in physical processes occurring as optical thicknesses increased above 0.20. This is the point where the 0.21 µm mode becomes significant. Our model also shows the salt mode at 1.3 µm increasing in volume density with increasing optical thickness, but that the coarse mode is uncorrelated with optical thickness.

Moisture variables and cloud fraction will be analyzed as possible factors in the growth of the 0.21 µm mode. Preliminary results show a strong diurnal cycle in the optical thickness measurements, suggesting a strong relationship between aerosol optical thickness and boundary layer convection. This relationship appears to be stronger than the relationship between the aerosol optical thickness and cloud fraction. However, these results are preliminary and additional data are being analyzed.

2. <u>Algorithm Development</u>

The revised Algorithm Theoretical Basis Document was completed for the atmospheric corrections for the surface reflectance by E. Vermote and L. Remer with C. Justice, Y.J. Kaufman and D. Tanré. No major changes to the algorithm are proposed in the revised document. The sole product of the algorithm will be the spectral surface reflectance. A research agenda was added to emphasize the need to continue development of specific pieces of the algorithm and validation of the algorithm as a whole.

Good reviews of the ATBDs were received. Most of the rankings were "A"s and "B"s. One "C" was given to the algorithm for remote sensing of aerosol.

A review paper on the effect of aerosol on remote sensing was written by Kaufman and Tanré to a special issue of remote sensing of the environment.

3. Planning for SCAR-C

The SCAR-C (Smoke Clouds And Radiation - California) field experiment is planned for September/October '94. The main objectives are to collect data for development and validation of the MODIS fire detection and smoke aerosol detection algorithms, characterize the biomass burning and fire-produced smoke from remote sensing and in situ measurements, study the smoke interaction with clouds, characterize the background aerosol of the west coast, validate remote sensing algorithms and obtain images of dry zone vegetation for studies of surface reflectance in the visible and near-IR spectral regions. Other participants in SCAR-C include J.T. Suttles, B. Holben and C. Justice of NASA, P. Hobbs, D. Hegg and R. Ferek of Univerisity of Washington, L. Flynn of the Unversity of Hawaii, D. Ward and R. Ottmar of the U.S.D.A, Paulo Artaxo from U. Sao Paulo and C. Louisse from Lowrance Livermore lab.. Two planning meetings have been held, one on February 16 and one on May 17. Another meeting is planned for August 18 in Seattle.

The plan for SCAR-C calls for 2-3 pre-set fires in northern Oregon/southern Washington during the period 19 September - 7 October '94. One specific site has been designated at Pendleton, Oregon. One or two additional sites will be selected before the August meeting. The forest service will ignite and monitor the fires, the Univ. of Washington C-131A aircraft, based in Seattle, will make in situ measurements of the smoke plume and any capping clouds produced from the fire, the ER-2, based at Moffet Field, will make remote sensing measurements using the MODIS Airborne Simulator (MAS) and AVIRIS. The plan calls for the MAS to be fully integrated onto the ER-2 in its 12-bit, 50 channel configuration. There will be a short turn-around time between the return of MAS from BOREAS and its readiness for SCAR-C. In the event the 50 channel configuration is not ready by SCAR-C, a modified 12 channel configuration will be used instead. NASA/AMES will take responsibility for the MAS calibration with assistance from NASA/GSFC engineers and technicians in order to maintain continuity.

Four automatic sun/sky photometers will be deployed for SCAR-C. Two at selected burn areas (one at Pendleton), one in an agricultural burn area in the Willamette Valley in Oregon and one in an agricultural burn area in the Sacramento Valley of

California. In addition, a sun/sky photometer is already collecting data at the H.J. Andrews LTER site in Oregon.

4. MODIS 1.375-μm channel

We finished writing a paper on selection of the MODIS 1.375-μm channel for remote sensing of cirrus clouds from space and on its application for studing of the optical poperties of cirrus clouds. The paper was submitted to J. Atmos. Sci. in June (Gao and Kaufman, 1994).

Preliminay analysis shows that the information in this channel can be used for atmospheric corrections of the effect of thin cirrus on remote sensing, without the a priori knowledge of the detailed cirrus optical and physical properties.

5. Remote sensing of liquid water

Development of a new index, called the normalized difference water index (NDWI), which is a good measure of the information about liquid water content of vegetation canopy. The MODIS near-IR channels centered at 0.865 and 1.24 μm are used. Both channels are located in "atmospheric window" regions. NDWI is defined, similar to the definition of the widely used normalized difference vegetation index (NDVI), as:

$$NDWI = [r^*(0.865\ \mu m) - r^*(1.24\ \mu m)] \ / \ [r^*(0.865\ \mu m) + r^*(1.24\ \mu m)],$$

where r^* represent apparent reflectance (after correction of weak Rayleigh scattering effect for the 0.865-μm channel, and no Rayleigh correction is needed for the 1.24 μm channel). Solar radiation at 0.865 μm is strongly reflected by vegetation canopies. Solar radiation at 1.24 μm is weakly absorbed by vegetation liquid water. Both the 0.865 and 1.24 μm channels are not saturated when the leaf area index (LAI) is relatively large (4 or greater). As a result, NDWI is a very sensitive index for measuring the liquid water content of vegetation canopies.

The red channel (~0.65 μm) used in NDVI is saturated when LAI reaches 1, because the red channel is located near the center of the strong vegetation chlorophyll absorption band. NDWI overcomes this saturation problem. Combinations of NDVI and NDWI can provide improved descriptions of the status of vegetation canopies.

The values of NDWI are positive for areas covered by green vegetation, and mostly negative for areas covered by dry vegetation and soils. We have compared images of NDWI and NDVI derived from spectral images acquired with the NASA/JPL Airborne Visible/Infrared Imaging Spectrometer (AVIRIS). NDWI does overcome the saturation problem of NDVI.

Note that NDWI is expected to be much less dependent on aerosol effect than NDVI. This is a result of the longer wavelegths (aerosol effect is on average inversely proportional to the wavelegth) and due to the higher surface reflectance in these channels than in the red channel. The aerosol effect is minimal, close to zero for surface reflectace in the range 0.2-0.3 (the range depends on the aerosol singlescattering albedo).

6. Aerosol effect on radiative forcing and climate

SCAR-A data were used to derive the aerosol scattering phase function and from that the backscattering by aerosol of sunlight back to space. This scattering may cause the climate system to cool or decrease the greenhouse warming. Results were presented in the AMS conference. Similar analysis is being performed to measuements from Brazil of smoke aerosol.

A review paper on remote sensing of the aeosol forcing on climate was written (Kaufman, 1994) for the Dahlem conference of experts in aeorosol forcing of climate.

The AVHRR data set over Brazil was analyzed for the effect of smoke on the properties of clouds. By applying the analysis also to small and thinner clouds an increase in the cloud reflectance by 0.1 (from 0.4 to 0.5) was detected, accompanied by a reduction by 40% in the cloud drop size. For high amount of smoke the drop size does not decrease any more and the cloud reflectance decreases due to the presence of black carbon.

7. EFFECT OF VARIATIONS IN SUPERSATURATION ON THE FORMATION OF CLOUD CONDENSATION NUCLEI Kaufman and Tanré (*1994*). Abstract:

Sulfate aerosols can cool the climate by increasing the concentration of cloud condensation nuclei (CCN) and forming more reflective clouds. The magnitude of this effect is very uncertain. Recent calculations indicate that at most 6% of the anthropogenic sulfur emission forms new particles, while 44% adds mass to existing sulfate particles activated in clouds. It was assumed that sulfate added to existing particles does not increase the CCN concentration because, for a fixed supersaturation, those particles were already CCN. This implies that previous assessments of the sulfate effect on climate by cloud modification were overestimated. Although it was proposed that sub-CCN-size particles can grow to CCN-size in clouds, this was thought to require large supersaturations present in cumuliform clouds rather than in marine stratiform clouds that are most important for radiative forcing. Here we show that variability of even low average supersaturations allows particles as small as 0.015 μm to grow and become CCN. This process can quadruple the concentration of CCN and increase the corresponding aerosol effect on climate.

8. Meetings

Bo-Cai Gao, Yoram Kaufman and Lorraine Remer attended the AMS conference in Nashville TN, 24-26 January.

Yoram Kaufman participated upon invitation in the Dahlem conference of experts on aerosol focing of climate.

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